91-05271/

COMPLIMENTARY COPY
Please Credit Ontario Hydro Research if
Reproduced in Whole or in Part

ontario hydro
research division

To: Mr. B.J. Murdoch
Manager
Retube Engineering Department
In-Service Nuclear Projects

LSFCRP FOR BRUCE 'A' NGS
OPTIMIZATION OF FAST INDUCTION HEATING PROCESS
FOR C/T-CTI-R/J SEPARATION

J.T. Lee

ABSTRACT

This report summarizes the results of the development program conducted to optimize the Fast Induction Heating process for Calandria Tube - Calandria Tube Insert - Rolled Joint (C/T-CTI-R/J) separation. As a result of the optimization program, the R/J separation process, which previously required one hour and eleven minutes per R/J, can now be shortened to less than one minute. This significantly reduces the reactor's downtime and man-rem exposure, and can result in substantial dollar savings. This optimized process will be used for the Large Scale Fuel Channel Replacement (LSFCR) of Bruce 'A' NGS.

job	file	date	report no.
740615-155	823.45	December 13, 1990	90-306-K

LEGAL NOTICE

This report was prepared by Ontario Hydro and, while effort has been made to assure the accuracy and applicability of the material contained herein, neither Ontario Hydro nor any person acting on its behalf:

(a) makes any warranty, express or implied with respect to the use of any information, apparatus, method or process disclosed in this report or that such use may not infringe privately owned rights; or

(b) assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method or process disclosed in this report.

INTRODUCTION

The Fast Induction Heating process was developed for the Single Fuel Channel Replacement (SFCR) program and was successfully demonstrated in separating the C/T-CTI-R/Js in both the Pickering 'A' NGS (P2G16) and the Bruce 'A' NGS (B2N06). The principle objective of the SFCR program was to release a small number of C/T-CTI-R/Js on an emergency basis. Optimization of the process was not necessary. However, for the Large Scale Fuel Channel Replacement (LSFCR) program, in which a large number of C/T-CTI-R/Js are needed to be released, substantial time savings can be achieved from process improvement. Process optimization would significantly reduce the downtime of the reactor(s) and man-rem exposure, and substantial dollar savings can be realized.

BACKGROUND

The Fast Induction Heating process loosens the calandria tube and the calandria tube insert by shrinking them radially, thus making it possible for easy removal.

The Fast Induction Heating process used at P2G16 and B2N06 consisted of three heating and cooling cycles, and are outlined as follow:

Activity	Duration	Cooling time
Warm-up cycle	10 s.	10 min.
First power cycle	33 s.	60 min.
Second power cycle	23 s.	

To release a rolled joint using the above process, a minimum of one hour and eleven minutes is needed. By reducing the number of heating cycles from three to one, significant time savings result, while maintaining the reliability of the separation process.

OBJECTIVES AND CONSTRAINTS

The objective of the optimization program is to develop a simple and reliable process which can reduce the number of heating cycles required to separate the C/T-CTI-R/J from three to one.

The main constraints for the separation process are:

a) The metallurgical transformation temperature of the tubesheet material (622°C) cannot be exceeded.
b) The melting temperature of the CTI should not be approached.
c) The maximum pulling force of 6000 pounds for the C/T and the CTI cannot be exceeded.

DEVELOPMENT PROGRAM

To meet the above objectives and constraints, a development program was derived in cooperation with Retube Engineering Department and Reactor Mtce Concepts & Planning Department. The outlined activities consisted of theoretical and experimental simulation and analysis of the C/T-CTI-R/J separation process. The following is a brief summary of these activities:

Water Entrapped in C/T-R/Jm

In order to establish the feasibility of eliminating the warm-up cycle from the C/T-CTI-R/J separation process, two Bruce type water injected R/Js were shock heated {1}.

The R/Js were shock heated using the same process parameters as established for B2N06, without the warm-up cycle. No visual damage to the T/Ss was observed.

Computer Modelling

Computer modelling was used to investigate the shrinkage mechanism involved in the Fast Induction Heating process. This modelling makes use of an elaborate CAD system consisting of electromagnetic, thermal and stress analysis. The results of this study are detailed in Reference {2}. In short, the shrinkage process is dependant on the amount of inward expansion of the tube sheet and the temperature profile of the C/T and CTI at the end of the heating cycle.

Experimental Studies

In order to meet the time constraint, all hardware developed for the SFCR program was left unchanged. The process was optimized by varying the combination of process parameters.

Experiments were carried out to find a set of process parameters which would provide the maximum shrinkage on both the C/T and CTI. These parameters include:

- heating power
- heating duration
- coil position.

In the optimization program, the effects of high power heating, pre-soaking (low power heating followed by high power heating), variations of heating duration, and variations of heating coil positioning (nominal, 1/4" inboard & 1/8" inboard) were investigated where nominal coil position is the induction heating coil placement, used in both the P2G16 and B2N06 SFCR program.

Experimental Results

It was found that high power heating and pre-soaking gave similar shrinkage results. A coil position of 1/4" inboard provides superior C/T shrinkage over nominal coil position, while the CTI shrinkage is slightly worse with the 1/4" position. However, due to the improved shrinkage on the C/T and reduced shrinkage on the CTI, the C/T tends to shrink onto the CTI and they can't be separated within the imposed pulling force limit of 6000 pounds.

By using a coil position of 1/8" inboard and high power heating, three out of four R/Js were separated using the C/T-CTI pulling tool at force levels below the imposed limit. Slight welding between the C/T and CTI was experienced on one of the R/Js.

The above problem was alleviated by reducing the heating duration; three out of three R/Js were separated; and no evidence of welding was observed. The C/Ts and CTIs were removed using forces of less than 2100 pounds. The average shrinkage on the three C/Ts at the over-rolled area was 0.042". The average shrinkage on the three CTIs at the middle and the inboard portion of the CTI was 0.078", while the shrinkage at the outboard portion of the CTI was 0.062". Due to the intense electromagnetic field generated during the heating cycle, temperature measurement can only be read approximately eight seconds after the completion of the cycle. The three maximum extrapolated T/S surface temperatures, measured at one millimetre from the C/T surface, were 540°C, 515°C and 500°C respectively.

Final Process Parameters

The final process parameters used for releasing the last three R/Js are as follows:

- computer power setting of 130 (equivalent to 33.5 kW at the calorimeter)
- heating coil position of nominal +1/8" inboard.
- one heating and cooling cycle (28 seconds and 60 minutes respectively)

CONCLUSION & RECOMMENDATIONS

Theoretical and experimental studies have shown that the fast induction heating technique can be optimized to release the C/T-CTI-R/J with one heating cycle.

The T/S used in the final test was sent to AECL for analysis. The final process parameters may require slight modifications pending AECL feedback.

Since the simulations of water entrapped R/J were performed using process parameters established for three cycle separation, it is recommended that the simulation be repeated using the finalized process parameters to ensure the reliability of the process.

Approved:

A.F. Baljet
Manager
Electrical Research Department

Submitted:

J.T. Lee
Engineer
Stations & Underground Section
Electrical Research Department

GLP

REFERENCES

1. Memorandum from J. Lee to M. Cenanovic, "Shock Heating C/T-CTI-R/Js without Warm-up Cycle", June 6, 1990, File 823.45(T2).

2. Memorandum from M. Ng to M. Cenanovic, "The Fast Induction Heating Process For C/T Rolled Joint Separation", July 18, 1990, File 823.45(T3).